China Steel Technical Report, No. 25, pp. 15－18, (2012)

Central Segregation Improvement of No. 3 Bloom Caster at China Steel

MING-HUNG CHEN, CHEN-YUAN LU, KUAN-JU LIN, CHI-LUN KAO,
SHIH-YU HUANG, MING-FANG TSAI and A-NAN KUO

Iron and Steel Research & Development Department
China Steel Corporation

No. 3 bloom caster at China Steel (CSC) was not allowed to produce high carbon steels such as AISI 1082 due to central segregation. Many technologies and caster modifications were implemented to No. 3 bloom caster to improve the central segregation. The methods adapted were soft reduction with convex rollers, enhancement of the Mold Electromagnetic Stirrer (M-EMS) performance, optimization of the secondary cooling system, reinforcement of the frame structure of the withdrawing stand, and stabilization of the hydraulic system. After the implementation of the new technology, the central segregation C/C0 is steady and reduced significantly below 1.1.

Keywords: Central segregation, Soft reduction, High carbon steel, Bloom caster

1. INTRODUCTION

Central segregation is a major quality issue for high carbon steels such as tire cord, saw wire, AISI 1082 and pre-stressed wire. Severe central segregation causes the formation of network cementite in the centerline and results in the so-called “cap and cone” fracture morphology during the wire drawing process. Therefore, many technologies have been developed to eliminate central segregation, such as soft reduction(1), convex rollers(2,3), electromagnetic mold stirring(4,5), low superheat casting (4,5), and adding a steel strip into the mold(6). An advanced dynamic soft reduction technology has also been developed for bloom casting to increase the flexibility of production (7, 8).

Massive production of high carbon steel bloom with excellent central segregation control has been established at CSC since 1994(4-5, 9-10). Soft reduction, convex rollers and mold electromagnetic stirring were all adapted to improve the central segregation in No. 1 and No. 2 bloom casters. However due to equipment limits, the central segregation quality was still not acceptable when the same technologies were transferred to No. 3 bloom caster (hereafter denoted as B3). B3 was not qualified for massive production due to the central segregation C/C0 being scattered randomly and often exceeding the allowable limit as indicated in Fig.1. Therefore, some items were especially proposed to improve central segregation during the opportunity of the B3 revamping in 2011. The following paper describes the main revamping items and results relevant to the central segregation.

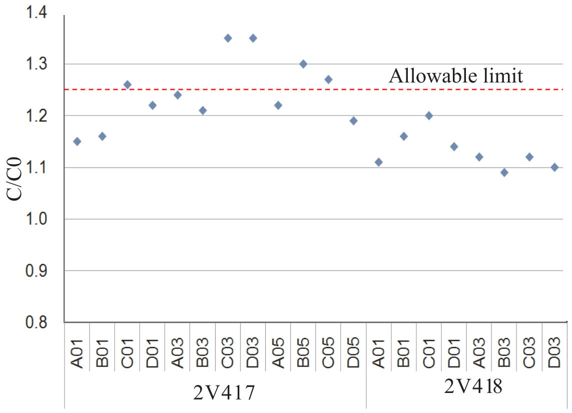

Fig.1. Central segregation C/C0 of AISI 1082 produced in No. 3 bloom caster after modification in 2005.

2. MODIFICATION OF WITHDRAWING STAND

B3 is a bow type, four strand bloom caster and its main specifications are listed in Table 1. Soft reduction is implemented by using the as-built three withdrawing rollers, so the withdrawing rollers play the roles of withdrawing and soft reduction simultaneously and the soft reduction is dominated by the squeezing force not the roller gap. The Strand Electromagnetic Stirrer (S-EMS) and the Final Electromagnetic Stirrer (F-EMS) are as-built equipments, but have now been completely removed because their metallurgical effects are not beneficial. Soft reduction trials showed that B3 central segregation C/C0 was not stable and that the rejection rate was too high. Two problems were found to cause the soft reduction to be invalid after checking the soft reduction performance and strand conditions. The first problem was the excessive roll pitch of the soft reduction. The excessive roll pitch induced severe bulging between the soft reduction rollers, which definitely discounted the metallurgical effect of soft reduction because the enriched molten steel was restricted within the bulging and finally solidified as segregation in the centerline. The second problem was the insufficient structural rigidity of the withdrawing stand. The as-built withdrawing stand used a single-column structure to support the withdrawing roller. When the withdrawing roller squeezed the bloom, it worked as a cantilever beam and caused the single-column structure to bend due to the reacting force from the bloom. The deflection of withdrawing structure caused the squeezing force and the gap to vary with time and resulted in the breaking down of the soft reduction. These two problems had to be solved first in order to improve the B3 central segregation.

Table 1 No. 3 bloom caster main specifications

Caster type	Bow type
Capacity	480,000 ton/year
Radius	11.2 m
Strands	4
Bloom size	220×260 mm^2
Casting speed	0.9 - 1.6 m/min
Metallurgical length	21m
Secondary cooling	Air mist
Soft reduction	Yes
M-EMS	Yes
S-EMS, F-EMS	No

The withdrawing stands were all modified in 2005 as summarized in Table 2. The original single-column structure was modified to a two-column structure so as to strengthen the mechanical structure and its robustness. The roller pitches were reduced from 2.4m to 1.2m based on a theoretical calculation to suppress the formation of excessive bulging. Convex rollers were also adapted so as to enhance the performance of the soft reduction and to reduce internal cracks. The hydraulic pressures of the squeezing cylinder were adjusted to optimize the squeezing force in line with the geometry of a convex roller.

However, soft reduction trials revealed that the improvement of central segregation C/C0 was much less than expected, as shown in Fig.1, and that B3 was still unqualified for producing high carbon steels. Internal technical reports concluded that two facility limits might have restricted the metallurgical effect of soft reduction. A previous study(5) showed that the M-EMS played an important role in improving central segregation. However, the B3 M-EMS design then in use was of the linear type and the maximum electric current was only 400A, so the B3 stirring force in the mold was less than that of the other bloom casters. Moreover, the first zone and apron of the secondary cooling zones were divided by narrow sides and wide sides, which made the cooling zone too long and resulted in a considerable hydraulic pressure drop. Uneven secondary cooling in the casting direction was formed in both the first zone and the apron. The cooling intensity in the lower part was much higher than that in the higher part. Thus, an uneven growth of shell thickness was generated and accurate soft reduction was difficult to apply.

4. CASTER REVAMPING

B3 revamping was launched in 2011 due to an integral bloom quality requirement and caster status concern. The whole strand structure and control system were all revamped, but the mechanical parts of the withdrawing stand were not included. Some revamping

Table 2 Summary of No. 3 bloom caster modification and revamping items

Item	As-built	Modification in 2005	Revamping in 2011
M-EMS	Linear type 400A max.	-	Rotary type 800A max.
Secondary cooling	First zone and Roller apron I/II: narrow sides and wide sides divided into 2 zones	-	First zone and Roller apron I/II: original 2 zones reconstructed. 2 zones remained but divided in casting direction
Roller apron I/II	Roller pitch 856mm	-	Roller pitch 641mm
Withdrawing and soft reduction	Roller pitch 2.4m Flat roller Single-column type withdrawing stand	Roll pitch 1.2m Convex roller Two-column type withdrawing stand	-

items related to improvement of the central segregation are listed in Table 2. The problems mentioned in the previous section were all addressed. Rotary type M-EMSs were adapted and the maximum electric current was increased to 800A. Consequently, the stirring force in the mold was strongly enhanced. The secondary cooling zones were redesigned and divided in the casting direction. The cooling intensity distribution in the casting direction was obviously improved and a new casting speed pattern was created as shown in Fig.2.

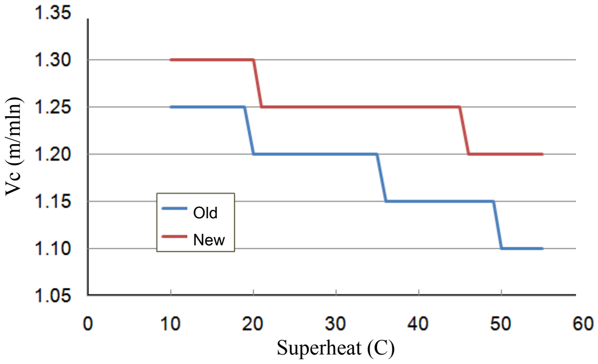

Fig.2. Casting speed patterns before and after No. 3 bloom caster revamping in 2011.

First two trials showed that the central segregation C/C0 was still not good as indicated in Fig.3, but better than before when compared with Fig.1. The improvement was presumed to be the contribution of the new M-EMS. However, B3 was very similar to the other bloom casters after revamping but there still existed an apparent difference in the central segregation C/C0. Therefore, many examinations have been done to confirm the functionality and actual output values. For example, the squeezing forces of the convex roller were checked by a specifically-designed instrument and the results showed that actual forces were 8% to 21% higher than the theoretical values. The actual casting speed was also found to be 2% slower than the setting value. Moreover, the different casting speeds and squeezing pressures were applied to different strands simultaneously in the first two trials to optimize the soft reduction parameters, but no obvious improvements were found.

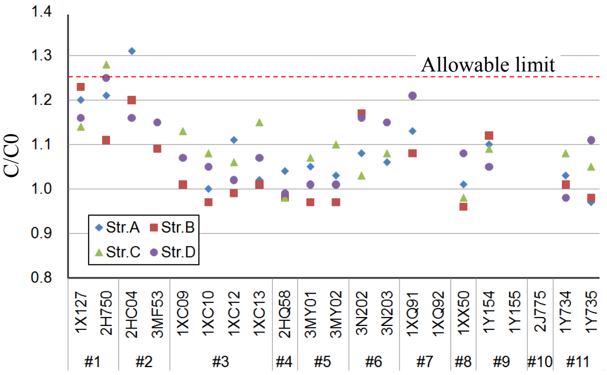

Fig.3. Central segregation C/C0 results of AISI 1082 in different trials after revamping in 2011.

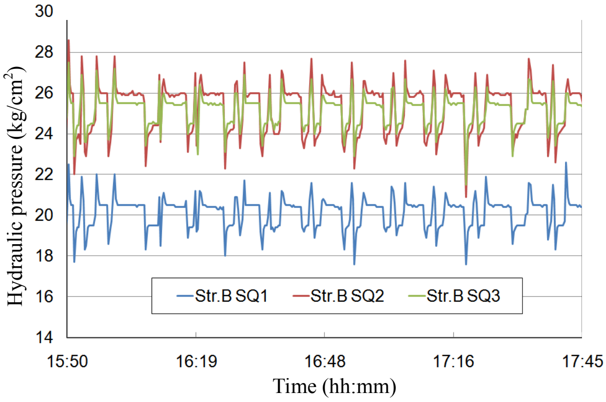

Fig.4. Hydraulic pressure variations of squeezing cylinder for soft reduction in the strand B of No. 3 bloom caster after revamping in 2011.

However, an unusual hydraulic pressure variation was found during the first two trials, as illustrated in Fig.4. The hydraulic pressures of three squeezing cylinder varied periodically and the amplitudes reached ±3kg/cm^2 corresponding to a squeezing force of ±1.5ton. In order to determine the influence of hydraulic pressure variation on roller gap, magnetostrictive position sensors were installed in the squeezing cylinders to monitor the real-time roller gap variation. The results showed that the roller gap varied with the hydraulic pressure. A hydraulic pressure drop of 5kg/cm^2 caused a roller gap increment of 0.7mm as shown in Fig.5. A previous study(10) had revealed that the reduction amount for each squeezing roller was approximately 1mm. A 0.7mm roll gap variation was approximately 70% of the reduction amount. So the hydraulic pressure variation might be the key factor influencing central segregation. The hydraulic pressure variation was found to be caused by the accumulation of greasy filth in the hydraulic system. After cleaning the system, the hydraulic pressure became very stable and the central segregation C/C0 was also clearly improved during the third trials, as illustrated in Fig.3. It was also found that a central segregation C/C0 aggravation always came with a hydraulic pressure variation as confirmed in the 6th and 7th trials. Thus a reliable hydraulic system is necessary for soft reduction process.

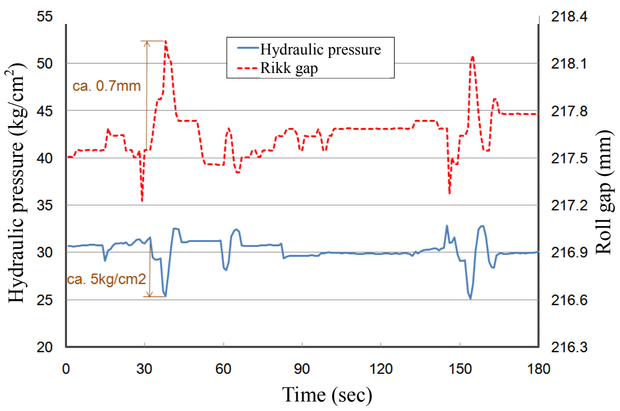

Fig.5. Relation between hydraulic pressure of squeezing cylinder and corresponding roller gap during AISI 1082 casting.

5. CONCLUSIONS

Originally the No. 3 bloom caster was not allowed to produce high carbon steels such as AISI 1082 due to central segregation. Even when technologies that had been successfully applied in other bloom casters were transferred to the No. 3 bloom caster, the central segregation was still not improved subject to equipment limits. Therefore, many modifications were implemented to the No. 3 bloom caster to improve the central segregation situation. After all the improvements were done, the central segregation C/C0 is stable and mostly below 1.1. The main modifications are summarized below:

1. The original frame structures of the withdrawing stand were prone to bend as the squeezing force was applied to bloom, which made the squeezing force for soft reduction unstable and uncontrollable. After modification the frame structure became stronger, so the squeezing force for soft reduction worked as expected.
2. Flat rollers were replaced by convex rollers to enhance the performance of soft reduction. A corresponding adjustment for hydraulic pressure of squeezing force was also performed.
3. The original M-EMS was of the linear type and the stirring force was weak due to the electric current being limited to 400A. A rotary type M-EMS with maximum electric current 800A was installed to enhance the stirring force.
4. As-built secondary cooling zones in first zone and apron were divided by narrow sides and wide sides, which made the zone was too long and resulted in an uneven cooling intensity in the casting direction. So the secondary cooling zones were reconstructed and divided into an upper zone and a lower zone to create a more uniform cooling intensity.
5. The hydraulic pressures from the squeezing cylinder provided for soft reduction were unstable with variations reaching ±3kg/cm^2 corresponding to a gap variation of 0.7mm. Central segregation C/C0 was improved obviously as the hydraulic pressure variation was eliminated.

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